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FINAL REPORT

**DETERMINATION OF FLAX STRAW FIBRE
CONTENT FROM SELECTED ACCESSIONS
GROWN BY PLANT GENETIC RESOURCES
CENTRE IN 1998 AND 1999**

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Determination of Flax Straw Fiber Content from Selected Accessions Grown by the Plant Gene Resources of Canada in 1998 and 1999

Biolin Research Inc.

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ABSTRACT

The bast fiber content of the straw from 1,409 selected flax accessions grown in 1998 and 1999 by PGRC in Saskatoon, Canada were estimated by retting and then extracting the bast fiber from the straw in the Biolin Research Inc. lab. The results showed that bast fiber contents varied from 8% to 35%. This data will be used by flax breeders to develop new flax varieties with elevated or lowered levels of fiber content and to help develop a NIR system that can be used to rapidly estimate fiber content in flax straw and roughly cleaned fiber.

EXECUTIVE SUMMARY

In February of 2000, Biolin Research Inc. ("Biolin") received funding from the Saskatchewan Flax Development Commission ("SaskFlax") and the Agriculture Development Fund ("ADF") of Saskatchewan Agriculture and Food to determine the fiber content¹ of the 1,409 straw samples that Biolin had collected and stored from Plant Gene Resources of Canada ("PGRC") accession plantings in 1998 and 1999.

Sub-samples of each straw sample were prepared and retted by staff of Biolin. Each sub-sample consisted of pieces of straw 19.1 cm long cut roughly 10 cm above the ground level. Most sub-samples consisted of 100 to 150 pieces that, when combined, made a bundle about 4.1 cm in diameter. Data was collected on the unretted dry weight, the wet retted weight and the dry retted weight of each sub-sample. A reciprocating blade-type breaker/decorticator was used to roughly separate clean bast fibers from the retted dry straw and final cleaning of the bast fibers was done by hand. The weight of the clean bast fiber extracted from each sub-sample was divided by the initial dry retted weight of the sub-sample of straw to determine the percentage of bast fiber present in each sub-sample of straw. The bast fiber and shives (i.e., the non-fiber portion) produced from each sub-sample were placed in labeled plastic bags and stored for possible further analysis. The data thus generated was combined with background data supplied by PGRC on each accession and put into a computer spreadsheet format to allow easy manipulation and sorting. Copies of this data are available from Biolin and have been sent to SaskFlax, ADF and to PGRC.

Before retting, sub-samples of straw from 200 of the flax accessions were sent to the USDA Russell Research Center in Athens, Georgia for analysis using a Near-Infra-Red (NIR) reflectance machine. Once wavelength patterns from these samples were generated and collected in a computer database, the straw was sent back to Biolin for retting, drying and determination of the percentage of bast fiber. After this was completed, the bast fiber and shives from each of these 200 sub-samples was once again sent back to the Russell Research Center for grinding and another round of analysis with the NIR machine. When this is completed, the database of wavelengths generated by whole and ground sub-samples will be analyzed with computer software to find which wavelength combinations are correlated most highly with the percentage of bast fiber in each sub-sample as determined by the Biolin decortication method.

The results of processing the 1,409 accessions showed bast fiber content ranging from a high of 35% to a low of 8%. Table 1 presents a summary of the distribution of fibers contents of the 1,409 accessions. From a plant breeder's point of view, this information opens up a wide range of possibilities since it means that there is a wide range of fiber contents in the germplasm held in the PGRC collection. The results also show that

¹ The vast majority of cellulosic-based fiber in flax straw is found in the inner bark of the stem. This fiber is called "bast" fiber and is, for all applications except whole straw papermaking, the fiber of commerce. However, in addition to bast fibers there are tiny cellulosic fibers found in other parts of the stem. Although they are a relatively small percentage of the total cellulosic fiber found in flax stems, they can influence the yield, speed and quality of paper in a paper making process. Thus the total fiber content of flax straw is slightly higher than the bast fiber content. In this project, we estimated the bast fiber content and not the total fiber content because it is much easier to measure and most processors of flax straw are only interested in the bast fiber content.

Table 1: Distribution of Bast Fiber Content in 1,409 Accessions

Fiber Content	Number of Accessions	Portion of Total Accessions
>30%	19	1.3%
25.0-29.9%	154	10.9%
20.0-24.9%	742	52.7%
15.0-19.9%	452	32.1%
10.0-14.9%	38	2.7%
<10%	4	0.3%

newer fiber flax varieties tend to have higher fiber contents than older fiber flax varieties and that some oilseed flax varieties that were bred for Prairie conditions have fiber contents which are higher than older fiber flax varieties. The data also indicates that some commonly grown oilseed varieties (e.g., Flanders, CDC Arras, AC Watson, AC Camduff) have from 30-50% more fiber in their stems than other commonly grown varieties (e.g., Norlin, AC Linora, Somme, AC McDuff).²

This data will be used by flax breeders to develop new flax varieties for the Prairies with elevated or lowered levels of fiber content and to provide base data needed to develop a NIR system that can be used to rapidly estimate fiber content in flax straw and roughly cleaned fiber. The eventual development of a NIR system to measure bast fiber content should allow buyers and sellers of flax straw and roughly cleaned fiber to improve the transparency and fairness of their commercial transactions (i.e., a farmer producing straw with a higher fiber content should get a higher price for his straw) and to provide a cheap and reliable tool that can be used to improve the fiber yield and/or consistency of the products they are producing (i.e., processors should be able to quickly monitor the effect of different machinery settings on the cleanliness level of the fiber they are processing).

The reader should keep in mind that bast fiber content is only one of the characteristics that determines the amount of fiber that can be produced from a given area of land. Some of the variables which are very important but not considered here include the height of the flax plants, the number of the flax plants in a given area and the average stem diameter of the flax plants. Soil fertility, growing conditions and level of maturity at straw harvest have also been shown to have a significant influence on, not only on the fiber content, but also on fiber quality. The mandate of this project was to look only at fiber content and not at fiber quality and hence, at this time, we can not make comments on the quality of the fiber that might be produced from different accessions.

The detailed results of processing the 1,409 accessions have been printed out in Appendix A. Due to its large physical size, (i.e., 64 pages) we think most potential users of this data will find it easier to find and/or manipulate the information found in Appendix A by getting an electronic spreadsheet version (Excel format) of this information from Biolin or the funders of this project.

² See the Results and Discussion Section for a more complete list.

Background and Objectives

Background

Farmers in Western Canada seed roughly two million acres of flax every year and consequently produce roughly half a tonne of residual straw per acre. Only 10-15% of this straw is collected and used in their manufacture of specialty papers and plastic components. The flax straw that is not removed from the field for these uses is normally burnt or chopped and spread. Unfortunately both these options cost a farmer time and money and are increasingly creating negative environmental impacts.

Recent market surveys and on-going research indicate that there are many potential products that could utilize flax fibers to compliment or replace glass, synthetic and cotton fibers. If flax fibers were used more extensively in such products, it would increase the demand for flax straw and hence both reduce the amount of flax straw that is burnt and increase the revenue farmers could get from growing flax.

Most of the potential new products that could be made from flax are made by large industrial concerns that purchase glass, synthetic and cotton fibers by specifying the characteristics they must have in the fiber they are using (e.g., fiber fineness). At the present time, flax fibers and straw are only purchased on the basis of samples. Such a system is not acceptable to most potential non-traditional users of flax fibers. Hence there is a need to develop standard, fast and cheap ways to measure selected characteristics of flax fiber and straw. In this regard, Alvin Ulrich of Biolin Research Inc. ("Biolin") has been in contact with USDA staff at the Russell Research Center in Athens, Georgia who are working on developing a Near Infra Red (NIR) system of measurement for flax fiber and straw.

Objectives

1. To determine the fiber content of flax straw that was collected in 1998 and 1999 from 1,409 flax accessions grown by Plant Gene Resources of Canada ("PGRC") at the Agriculture and Agri-Food Research Farm in Saskatoon;
2. To help flax breeders make more desirable crosses in the future; and
3. To produce clean fiber and shive samples that can be used to develop a rapid, consistent and low cost method of determining fiber content in flax straw with the use of NIR technology.

Experimental Methods

- Flax accessions were grown in single rows.
- Staff of PGRC harvested straw samples by cutting the straw two inches above ground using a single row Japanese rice harvester after the seed bolls were cut off with a hand-held motorized clipper.

- Straw samples were left in the field to sun bleach and dry.
- Samples were gathered and placed in tagged paper bags with tags attached to the samples.
- Samples were stored in a covered outdoor shelter, until they were processed at the Biolin Research Laboratory.
- When possible, a sub-sample bundle of straw of 19.1 cm in length and 4.1 cm in diameter was taken from each straw sample gathered from the PGRC plots. In cases where very little straw was produced; the sub-sample consisted of all the straw that was gathered from the field. Thus each bundle represented one accession. After bundling, each sub-sample was bound with two elastic bands and tagged with a plastic-coated label.
- Batches of approximately 150 bundles were retted in a warm water tank for four to six days until the results of the Fried shake test showed that the majority of bundles were optimally retted. This test involved placing fifteen pieces of retting straw, each approximately 10.0 cm in length and each from a different bundle, in fifteen test tube half full of boiling water with one piece of straw in each test tube, stoppering the test tubes and placing them in a machine in the Biolin lab designed to violently shake test tubes for fifteen seconds. After shaking, the straw in each test tube was visually scored for loose fibers on a whole number scale from "0" to "3" with "0" representing no loose fibers and "3" representing total loosening of all bast fibers on the stem. When the average score was above 2.8 and there were no "0" scores and at least twelve test tubes had a score of "3", the bundles³ in the batch were considered fully retted. The bundles were then taken out of the tank, rinsed in tap water and set in drying racks under a fume hood for approximately 4 days to dry.
- Dry bundles were weighed and the fiber was extracted using a reciprocating blade-type breaker/decorticator. The fiber was hand cleaned to the point where no shives were left on the fiber and little or no fiber could be found mixed with the shives. After cleaning, the fiber and shives were weighed and placed in separate sample bags and labeled with the same catalog number with a separate sub-catalog letter at the end to discern between the fiber and the shive bags.
- After all bundles were processed, a master spreadsheet was compiled with data containing moisture gain in retting process, moisture loss in drying, fiber content, shive content, dust and processing waste, and the accession information provided by PGRC.
- Before retting, sub-samples of straw from 200 of the flax accessions were sent to the USDA Russell Research Center in Athens, Georgia for analysis using a Near Infra Red (NIR) reflectance machine. Once wavelength patterns from these samples were generated and collected in a computer database, the straw was sent back to Biolin for retting, drying and determination of the percentage of bast fiber.

³ Because of the varying degrees of maturity between the different accessions, not all bundles were retted to the same degree. However, we had no way to easily deal with the problem of differential retting of bundles within a batch in one tank.

After this was completed, the bast fiber and shives from each of these 200 sub-samples was once again sent back to the Russell Research Center for grinding and another round of analysis with the NIR machine.

Results and Discussion

Results

The results of processing the 1,409 accessions showed bast fiber content ranging from a high of 35% to a low of 8%. The results also show that newer fiber flax varieties tend to have higher fiber contents than older fiber flax varieties and that some oilseed flax varieties that were bred for Prairie conditions have fiber contents which are higher than older fiber flax varieties bred for other parts of the world. Table 1 presents a summary of the distribution of fibers contents of the 1,409 accessions.

Table 1: Distribution of Bast Fiber Content in 1,409 Accessions

Bast Fiber Content	Number of Accessions	Portion of Total Accessions
>30%	19	1.3%
29.9-25.0%	154	10.9%
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The detailed results of processing the 1,409 accessions have been printed out in Appendix A. Due to its large physical size, (i.e., 64 pages) we think most potential users of this data will find it easier to find and/or manipulate the information found in Appendix A by getting an electronic spreadsheet version (Excel format) of this information from Biolin or the funders of this project. Appendix A and its corresponding spreadsheet show the bast fiber content of all the accessions that were processed as well as data on dry unretted weights, wet retted weights, dry retted weights and the background identification information provided by PGRC.

Table 2 shows the estimated bast fiber content of some common Canadian oilseed flax varieties. Some of the accessions had been grown two to six times within the two years in question and, in these cases, Biolin collected two to six samples of straw with the same accession name. The results of analyzing these replicates showed that, on the average, the bast fiber content of straw with the same accession name had a standard deviation of 2.3 percentage points (e.g., 19.9% $\pm$ 2.3%). Thus it is likely in field situations that the varieties with the higher fiber contents in Table 2 will, in most cases, have higher fiber contents than those at the bottom of the list. Although the raw data does not support tests of statistical differences, it gives some indication of the variability that may be expected because of genetic differences. (In a field situation, factors like planting density, growing conditions and soil fertility can also have a significant effect on the bast fiber yield.)

Table 2: Quick Ranking of Selected Canadian Oilseed Flax Varieties Based on Estimated % of Bast Fiber

Newer Varieties	%Bast Fiber	INDEX Vimy=100
Flanders	26.7	134
CDC Arras	25.2	127
AC Watson	24.3	122
AC Camduff	23.9	120
AC Emerson	22.1	111
CDC Bethune	21.1	106
Vimy	19.9	100
CDC Normandy	19.8	99
AC McDuff	19.3	97
Somme	19.2	96
AC Linora	17.2	86
Norlin	16.3	82
Linola 989 a/		
Linola 1084 a/		
Valour a/		

Older Varieties	% Bast Fiber	INDEX Vimy=100
Redwood 65	27.3	137
Rocket	26.5	133
Andro	24.1	121
Redwing	23.1	116
Linott	22.5	113
Dufferin	20.3	102

a/ No data available at this time.

Discussion

The accessions represent a wide range of flax types and required different lengths of time for the seed to mature. Staff of PGRC have a primary mandate to re-generate seed for the Gene Bank and hence arrange harvest activities to maximize the chance of getting viable seed. This means that the seed bolls are harvested and the straw cut when the majority of accessions have reasonably mature seed. When this happens, all accessions are harvested within a few days, even though some may still not be fully mature. Differences in straw maturity can affect fiber content and/or the speed of retting since the fiber content increases and the fibers becomes more lignified (i.e., they ret more slowly) as the straw matures. The varying degrees of maturity between different accessions and the fact that we tank retted the straw samples in batches of 150, meant that not all bundles were retted to the same degree and hence some samples were much more difficult to process than others. It also means that our data may show slightly higher fiber contents for accessions which matured earlier.

Some of accessions planted were from very old seed and produced relatively few plants in a single row. With little within row competition, such low plant densities tend

to result in flax plants with many tillers and/or with thick stems which, in turn, tends to produce stems with lower fiber contents. This means that our data may show somewhat lower fiber contents for accessions which produced only a few plants in a standard row length.

The reader should keep in mind that bast fiber content is only one of the characteristics that determines the amount of fiber that can be produced from a given area of land. Some of the variables which are very important but not considered here include the height of the flax plants, the number of the flax plants in a given area and the average stem diameter of the flax plants. Soil fertility, growing conditions and level of maturity at straw harvest have also been shown to have a significant influence on, not only on the fiber content, but also on fiber quality. The mandate of this project was to look only at fiber content and not at fiber quality and hence, at this time, we can not make comments on the quality of the fiber that might be produced from different accessions.

Conclusions and Impact

Conclusions

The clean fiber and shive samples produced during this project show that the bast fiber content of straw can be estimated with the method used by Biolin to carry out this project.

There are now estimates of the bast fiber content of 1,409 of the accessions in the PGRC collection. Although the raw data does not support tests of statistical differences, it gives a good indication of the wide variability that may be expected because of genetic differences.

Impact

From a plant breeder's point of view, this information opens up a wide range of possibilities since it means that there is roughly a fourfold difference in fiber contents of flax accessions in the PGRC collection and hence that there should be genetic ways to significantly elevate or lower the fiber content of flax varieties bred for the Prairies.

There appears to be significant differences between the bast fiber content of commonly grown Canadian oilseed flax varieties and the information presented in Table 2 should encourage more investigation in this area and the development of firmer guidelines for preferred oilseed flax varieties for fiber production for both farmers and processors.

The eventual development of a NIR system to measure bast fiber content should allow buyers and sellers of flax straw and roughly cleaned fiber to improve the transparency and fairness of their commercial transactions (i.e., a farmer producing straw with a higher fiber content should get a higher price for his straw) and to provide a cheap and reliable tool that can be used to improve the fiber yield and/or consistency of the products they are producing (i.e., processors should be able to quickly monitor the effect of different machinery settings on the cleanliness level of the fiber they are processing).

Information of Benefit to Processors and Government

Since this information shows that there is a wide range of bast fiber contents possible, it should encourage processors and/or governments to provide funding and/or other support to plant breeders to develop flax varieties for the Prairies with elevated or lowered levels of bast fiber content depending on the expected end use of the straw. The knowledge that 200 samples of calibration fiber and shive samples are now available to develop a NIR system to quickly and cheaply measure bast fiber content in flax should encourage processors and governments to provide funds, if needed, to complete development of this method and/or to purchase and use NIR systems once they are developed.

Indications for Further Research

In most cases, the estimated bast content of an accession was based on the straw produced from a single row planted to that accession in one year at one location. Replicated, multi-location, multi-year trials should be set up with a selection of some of the accessions to get a clearer understanding of the natural variation that may occur in the bast fiber content of an accession when it is grown in a variety of locations and weather patterns. Further work should also be done to investigate if accessions generally respond in the same way to changes in soil fertility, rainfall, planting rates, planting depth, etc. There is also a need to look at how bast fiber quality traits (e.g., fiber fineness, fiber strength) vary among flax accessions.